INTERNATIONAL STANDARD

ISO 5165

Third edition
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Petroleum products — Determination of the ignition quality of diesel fuels — Cetane engine method

Produits pétroliers — Détermination de la qualité d'inflammabilité des carburants pour moteurs diesel — Méthode cétane

Reference number
ISO 5165:1998(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard 5165 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*.

This third edition cancels and replaces the second edition (ISO 5165:1992), of which it constitutes a technical revision.

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Petroleum products — Determination of the ignition quality of diesel fuels — Cetane engine method

WARNING – The use of this International Standard may involve hazardous materials, operations and equipment. This International Standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this International Standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This International Standard establishes the rating of diesel fuel oil in terms of an arbitrary scale of cetane numbers using a standard single cylinder, four-stroke cycle, variable compression ratio, indirect injected diesel engine. The cetane number provides a measure of the ignition characteristics of diesel fuel oil in compression ignition engines. The cetane number is determined at constant speed in a pre-combustion chamber-type compression ignition test engine. However, the relationship of test engine performance to full scale, variable speed, variable load engines is not completely understood.

This International Standard is applicable for the entire scale range from zero cetane number (CN) to 100 CN but typical testing is in the range of 30 CN to 65 CN.

This test may be used for unconventional fuels such as synthetics, vegetable oils, etc. However, the relationship to the performance of such materials in full scale engines is not completely understood.

Samples with fluid properties that interfere with the gravity flow of fuel to the fuel pump or delivery through the injector nozzle are not suitable for rating by this method.

NOTE 1 This International Standard specifies operating conditions in SI units but engine measurements are specified in inch-pound units because these are the units used in the manufacture of the equipment, and thus some references in this International Standard include these units in parenthesis.

NOTE 2 For the purposes of this International Standard, the expression “% (*V/V*)” is used to represent the volume fraction of a material.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3015:1992, *Petroleum products – Determination of cloud point.*

ISO 3170:1988, *Petroleum liquids – Manual sampling.*

ISO 3171:1988, *Petroleum liquids – Automatic pipeline sampling.*

ISO 3696:1987, *Water for analytical laboratory use – Specification and test methods.*

ISO 4787:1984, *Laboratory glassware – Volumetric glassware – Methods for use and testing of capacity.*

ASTM D 613-95, *Standard test method for cetane number of diesel fuel oils.*

ASTM E 832-81, *Specification for laboratory filter papers.*

3 Principle

The cetane number of a diesel fuel oil is determined by comparing its combustion characteristics in a test engine with those for blends of reference fuels of known cetane number under standard operating conditions. This is accomplished using the bracketing handwheel procedure which varies the compression ratio (handwheel reading) for the sample and each of two bracketing reference fuels to obtain a specific ignition delay permitting interpolation of CN in terms of handwheel reading.

4 Definitions

For the purposes of this International Standard, the following definitions apply.

4.1
cetane number
Measure of the ignition performance of a diesel fuel oil obtained by comparing it to reference fuels in a standardized engine test. Ignition performance is understood to mean the ignition delay of the fuel as determined when the standard test engine is operated under controlled conditions of fuel flow rate, injection timing and compression ratio.

4.2
compression ratio
The ratio of the volume of the combustion chamber including the pre-combustion chamber with the piston at bottom dead center (b.d.c.) to the comparable volume with the piston at top dead center (t.d.c.)

4.3
ignition delay
Period of time between the start of fuel injection and the start of combustion. It is expressed in degrees of crank angle rotation.

4.4
injection timing; injection advance
Time in the combustion cycle at which fuel injection into the combustion chamber is initiated. It is expressed in degrees of crank angle.

4.5
handwheel reading
Arbitrary numerical value, related to compression ratio, obtained from a micrometer scale that indicates the position of the variable compression plug in the pre-combustion chamber of the engine.

4.6
cetane meter; ignition delay meter
An electronic instrument which displays injection advance and ignition delay derived from input pulses of multiple transducers (pickups).

4.7
injector opening pressure
Fuel pressure that overcomes the resistance of the spring which normally holds the injector nozzle pintle closed, and thus forces the pintle to lift and release an injection spray from the nozzle.

4.8
reference pickup
Transducer(s) mounted over the flywheel of the engine, triggered by a flywheel pointer, used to establish a t.d.c. reference and a time base for calibration of the ignition delay meter.

4.9
injector pickup
Transducer to detect motion of the injector pintle, thereby indicating the beginning of injection.

4.10
combustion pickup
Pressure transducer exposed to cylinder pressure to indicate the start of combustion.

4.11
primary reference fuels
Hexadecane (cetane), heptamethylnonane (HMN) and volumetrically proportioned mixtures of these materials which now define the CN scale by the relationship given in the following equation:

$$\text{CN} = \%\ \text{cetane} + 0,15\ (\%\ \text{HMN}) \quad \ldots (1)$$

NOTE 3 The arbitrary CN scale was originally defined as the volume percent of cetane in a blend with 1-methylnaphthalene (AMN) where cetane had an assigned value of 100 and AMN an assigned value of zero. A change from 1-methylnaphthalene to heptamethylnonane as the low CN ingredient was made in 1962 to utilize a material of better stability and availability. Heptamethylnonane was determined to have a CN of 15 based on engine calibration by the ASTM Diesel National Exchange Group, using blends of cetane and AMN as primary reference fuels. The use of 1-methylnaphthalene as a primary reference fuel is allowed.

4.12
secondary reference fuels
Volumetrically proportioned blends of two selected hydrocarbon mixtures designated “T fuel” (high CN) and “U fuel” (low CN) where each numbered paired set of “T fuel” and “U fuel” is calibrated by the ASTM Diesel National Exchange Group in various combinations by comparison to primary reference fuel blends.

4.13
check fuels
Diesel fuel oils calibrated by the ASTM Diesel National Exchange Group which provide a guide for an individual laboratory to check the cetane rating performance of a specific engine unit.

5 Reagents and reference materials

5.1 Cylinder jacket coolant, water conforming to grade 3 of ISO 3696. Water shall be used in the cylinder jacket for laboratory locations where the resultant boiling temperature is 100 °C ± 2 °C. Water with commercial glycol-based antifreeze added in sufficient quantity to meet the boiling temperature requirement shall be used when the laboratory altitude dictates. A commercial multi-functional water-treatment material should be used in the coolant to minimize corrosion and mineral scale that can alter heat transfer and rating results.

5.2 Engine crankcase lubricating oil. An SAE 30 viscosity grade oil meeting service classification SF/CD or SG/CE shall be used. It shall contain a detergent additive and have a kinematic viscosity of 9,3 mm^2/s to 12,5 mm^2/s at 100 °C and a viscosity index of not less than 85. Oils containing viscosity index improvers shall not be used. Multigraded lubricating oils shall not be used.

5.3 Cetane primary reference fuel, hexadecane with a minimum purity of 99,0 %, as determined by chromatographic analysis, shall be used as the designated 100 cetane number component.

5.4 Heptamethylnonane primary reference fuel, 2,2,4,4,6,8,8-heptamethylnonane with a minimum purity of 98 % as determined by chromatographic analysis shall be used as the designated 15 cetane number component.

5.5 Secondary reference fuels, volumetric blends of two diesel fuels having widely different cetane numbers that have been round-robin engine calibrated by a recognized exchange testing group.

NOTE 4 Blends of “T fuel” and “U fuel” that have been engine calibrated by the ASTM Diesel National Exchange Group may be and typically are used for routine testing. The calibration data are incorporated in blend tables that list the cetane numbers assigned for various volume percentage blends of “T fuel” and “U fuel”. “T fuel” typically is in the range of 73 CN to 75 CN and “U fuel” typically is in the range of 20 CN to 22 CN. These fuels are available from Phillips 66 Company, Bartlesville, OK, USA and are examples of suitable products available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of these products.

NOTE 5 Storage and use of "T fuel" and "U fuel" should be at temperatures above 0 °C to avoid potential solidification, particularly of "T fuel". Before a container that has been stored at low temperature is placed in service, it should be warmed to a temperature of at least 15 °C above its cloud point as determined in accordance with ISO 3015. It should be held at this temperature for a period of at least 30 min and then the container should be thoroughly remixed.

5.6 Check fuels. Diesel fuel oils typical of the middle distillate type that have been engine calibrated by the ASTM Diesel National Exchange Group.

NOTE 6 Low cetane check fuel will typically be in the range of 38 CN to 42 CN. High cetane check fuel will typically be in the range of 50 CN to 55 CN.

6 Apparatus

6.1 Test engine assembly

As shown in figure 1 and comprising a single cylinder engine consisting of a standard crankcase with fuel pump assembly, a cylinder with separate head assembly of the pre-combustion type (see figure 2), thermal-siphon recirculating jacket coolant system, multiple fuel tank system with selector valving, injector assembly with specific injector nozzle, electrical controls, and a suitable exhaust pipe. The engine shall be belt connected to a special electric power-absorption motor which acts as a motor driver to start the engine and as a means to absorb power at constant speed when combustion is occurring (engine firing). ASTM D 613, Annex A2 (Engine Equipment Description and Specifications) lists all critical, non-critical and equivalent engine equipment which shall apply for this International Standard.

6.2 Instrumentation

An electronic instrument to measure injection and ignition delay timing as well as conventional thermometry, gauges and general purpose meters. ASTM D 613, Annex A3 (Instrumentation Description and Specifications) lists all critical, non-critical and equivalent instrumentation which shall apply for this International Standard.

NOTE 7 Engine equipment and instrumentation are available from the single source manufacturer, Waukesha Engine Division, Dresser Industries, Inc., 1000 West St. Paul Avenue, Waukesha, WI 53188, USA, fax: +1 414-549-2960. Waukesha Engine Division also has authorized sales and service organizations in selected geographic areas.

6.3 Reference fuel dispensing equipment

Calibrated burettes or volumetric ware having a capacity of 400 ml to 500 ml and a maximum volumetric tolerance of ± 0,2 %. Calibration shall be verified in accordance with ISO 4787. Burettes shall be outfitted with a delivery valve and delivery tip to accurately control dispensed volumes. The delivery tip shall be of such size and design that shut-off tip discharge does not exceed 0,5 ml. The rate of delivery from the dispensing system shall not exceed 500 ml/min.

NOTE 8 ASTM D 613, Appendix X1 (Reference Fuel Blending Apparatus and Procedures) provides additional information for application of this International Standard.

6.4 Injector nozzle tester

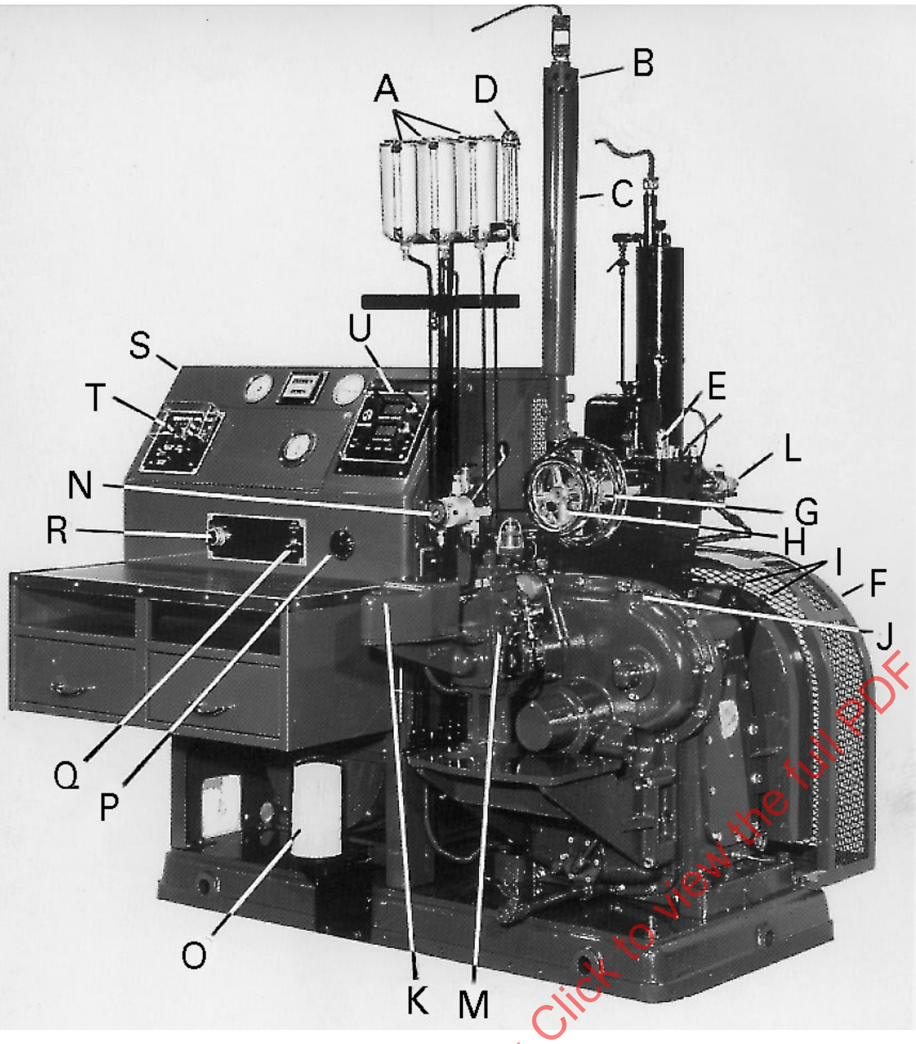
The injector nozzle assembly shall be checked whenever the injector nozzle is removed and reassembled to ensure that the initial pressure at which fuel is discharged from the nozzle is properly set.

NOTE 9 It is also important to inspect the type of spray pattern which occurs. Commercial injector nozzle testers which include a lever-operated pressure cylinder, fuel reservoir and pressure gauge are available from several sources as common diesel engine maintenance equipment.

6.5 Special maintenance tools

A number of specialty tools and measuring instruments are available for easy, convenient and effective maintenance of the engine and testing equipment.

NOTE 10 Lists and descriptions of these tools and instruments are available from the manufacturers of the engine equipment and those organizations offering engineering and service support for this International Standard.



Key

A Fuel tanks
B Air heater housing
C Air intake silencer
D Fuel flow-rate burette
E Combustion pickup
F Safety guard
G Variable compression plug handwheel
H V.C.P. locking handwheel
I Flywheel pickups
J Oil filter cap
K Injection pump safety shutoff solenoid
L Injector assembly
M Fuel injection pump
N Fuel selector valve
O OIl filter
P Crankcase oil heater control
Q Air heater switch
R Engine start-stop panel
S Instrument panel
T Intake air temperature controller
U Dual digital cetane meter

Figure 1 — Cetane method test engine assembly

7 Sampling and sample preparation

Samples shall be collected in accordance with ISO 3170, ISO 3171 or an equivalent National Standard.

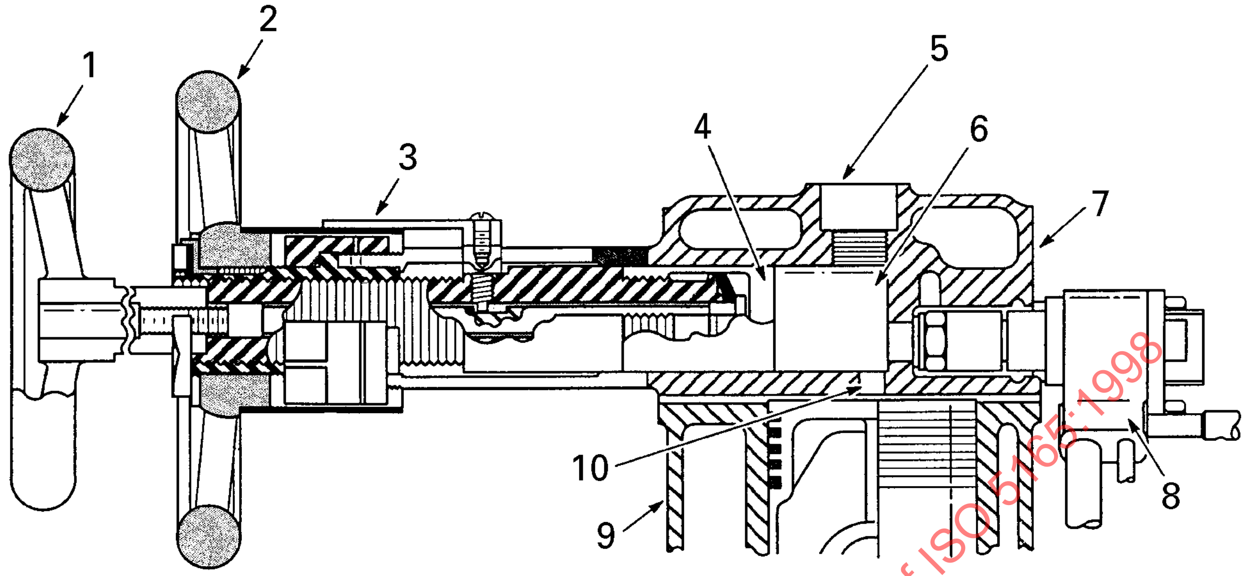
Samples shall be brought to room temperature, typically 18 °C to 32 °C, before engine testing. If necessary, samples shall be filtered through a Type 1, Class A filter paper, conforming to ASTM E 832, at room temperature and pressure before engine testing.

8 Basic engine and instrument settings and standard operating conditions

8.1 Installation of engine equipment and instrumentation

Locate the cetane test engine in an area where it will not be affected by certain gases and fumes that may have a measurable effect on the CN test result.

Installation of the engine and instrumentation requires placement of the engine on a suitable foundation and hook-up of all utilities. Engineering and technical support for this function is required, and the user shall be responsible to comply with all local and national codes and installation requirements. Proper operation of the test engine requires assembly of a number of engine components and adjustment of a series of engine variables to prescribed specifications. Some of these settings are established by component specifications, others are established at the time of engine assembly or after overhaul and still others are engine-running conditions that shall be observed and/or determined by operator adjustment during the testing process.



Key

1	V.C.P. locking wheel	6	Precombustion chamber
2	V.C.P. handwheel	7	Cylinder head
3	V.C.P. micrometer	8	Injector nozzle assembly
4	Variable compression plug	9	Cylinder
5	Combustion pickup hole	10	Turbulence passage

Figure 2 — CFR engine cylinder head and handwheel assembly

8.2 Engine speed

The engine speed shall be 900 r/min ± 9 r/min when the engine is operating with combustion with a maximum variation of 9 r/min occurring during a rating. Engine speed when combustion is occurring shall not be more than 3 r/min greater than for motoring without combustion.

8.3 Valve timing

The engine shall use a four-stroke cycle with two crankshaft revolutions for each complete combustion cycle. The two critical valve events are those that occur near top-dead-center (t.d.c.); intake valve opening and exhaust valve closing. Intake valve opening shall occur 10,0° ± 2,5° after-top-dead-center (a.t.d.c.) with closing at 34° after-bottom-dead-center (a.b.d.c.) on one revolution of the crankshaft and flywheel. Exhaust valve opening shall occur 40° before-bottom-dead-center (b.b.d.c.) on the second revolution of the crankshaft or flywheel with closing at 15,0° ± 2,5° a.t.d.c. on the next revolution of the crankshaft or flywheel. ASTM D 613, Annex A4 (Apparatus Assembly and Setting Instructions) defines the procedures for camshaft timing which shall apply for this International Standard.

8.4 Valve lift

Intake- and exhaust- cam lobe contours, while different in shape, shall have a contour rise of 6,223 mm to 6,350 mm (0,245 in to 0,250 in) from the base circle to the top of the lobe so that the resulting valve lift shall be 6,045 mm ± 0,05 mm (0,238 in ± 0,002 in). ASTM D 613, Annex A4 (Apparatus Assembly and Setting Instructions) defines the procedures for measuring valve lift which shall apply for this International Standard.

8.5 Fuel pump timing

Closure of the pump plunger inlet port shall occur at a flywheel crank angle between 300° and 306° on the engine compression stroke when the fuel flow-rate-micrometer is set to a typical operating position and the variable timing device lever is at full advance (nearest to operator). See ASTM D 613, Annex A4 (Apparatus Assembly and Setting

Instructions) for detailed instructions on setting and checking the fuel pump timing which shall apply for this International Standard.

8.6 Fuel pump inlet pressure

A minimum fuel head established by assembly of the fuel tanks (storage reservoirs) and flow-rate-measuring burette so that the discharge from them is 635 mm ± 25 mm above the centerline of the fuel injection pump inlet.

8.7 Direction of engine rotation

Clockwise rotation of the crankshaft shall occur when observed from the front of the engine.

8.8 Injection timing

This shall occur 13,0° b.t.d.c. for the sample and reference fuels.

8.9 Injector nozzle opening pressure

This shall be 10,3 MPa ± 0,34 MPa.

8.10 Injection flow rate

This shall be (13,0 ± 0,2) ml/min [(60 ± 1)s/13,0 ml].

8.11 Injector coolant passage temperature

This shall be 38 °C ± 3 °C.

8.12 Valve clearances

Setting the clearance between each valve stem and valve rocker half-ball to the following approximate measurements, upon assembly with the engine cold prior to being operated, will typically provide the controlling engine-running and hot clearance:

— intake valve 0,075 mm (0,004 in);

— exhaust valve 0,330 mm (0,014 in).

These clearances should ensure that both valves have sufficient clearance to cause valve seating during engine warm-up. The adjustable-length valve push rods shall be set so that the valve rocker adjusting screws have adequate travel to permit the final clearance setting. Engine running and hot clearance for both intake and exhaust valves shall be set to 0,20 mm ± 0,025 mm (0,008 in ± 0,001 in) measured under standard operating conditions with the engine running at equilibrium conditions on a typical diesel fuel oil.

8.13 Oil pressure

This shall be 172 kPa to 207 kPa.

NOTE 11 The CFR engine unit is equipped with a pressure gauge in psi and the oil pressure shall be 25 psi to 30 psi. ASTM D 613, Annex A4 (Apparatus Assembly and Setting Instructions) defines the adjustment procedure which shall apply for this International Standard.

8.14 Oil temperature

This shall be 57 °C ± 8 °C.

NOTE 12 The CFR engine unit is equipped with a temperature gauge in degrees Fahrenheit and the oil temperature shall be 135 °F ± 15 °F.

8.15 Cylinder jacket coolant temperature

This shall be 100 °C ± 2 °C.

8.16 Intake air temperature

This shall be 66 °C ± 0,5 °C.

8.17 Basic ignition delay

This shall be 13,0° for the sample and the reference fuels.

8.18 Cylinder jacket coolant level

Treated coolant added to the cooling condenser/cylinder jacket to a level just observable in the bottom of the condenser sight-glass, with the engine cold prior to being operated, will typically provide the controlling engine, running and hot operating level.

8.19 Engine-crankcase lubricating oil level

The controlling engine-running and hot operating level of the oil in the crankcase shall be approximately mid-position in the crankcase sight-glass.

NOTE 13 Oil added to the crankcase so that the level is near the top of the sight-glass, with the engine cold prior to being operated, will typically provide this condition.

8.20 Crankcase internal pressure

As measured by a gauge or manometer connected to an opening to the inside of the crankcase through a snubber orifice to minimize pulsations, the pressure shall be less than zero (a vacuum) and typically from 25 mm to 150 mm of water less than atmospheric pressure. Vacuum shall not exceed 254 mm of water.

8.21 Exhaust back-pressure

As measured by a gauge or manometer connected to an opening in the exhaust surge tank or main exhaust stack through a snubber orifice to minimize pulsations, the static pressure should be as low as possible, but shall not create a vacuum nor exceed 254 mm of water differential in excess of atmospheric pressure.

8.22 Exhaust and crankcase breather system resonance

The exhaust and crankcase breather piping systems shall have internal volumes and be of such length that gas resonance does not result.

NOTE 14 ASTM D 613, Appendix X2 (Operating Techniques) provides a suitable procedure to determine if resonance exists in the application of this International Standard.

8.23 Piston over-travel

Assembly of the cylinder to the crankcase shall result in the piston protruding above the top of the cylinder surface 0,381 mm ± 0,025 mm (0,015 in ± 0,001 in) when the piston is at t.d.c. Proper positioning is accomplished through the use of plastic or paper gaskets, available in several thicknesses and selected by trial and error for assembly between the cylinder and crankcase deck.

8.24 Belt tension

The belts connecting the flywheel to the absorption motor shall be tightened, after the initial break-in so that, with the engine stopped, a 2,25 kg weight suspended from one belt halfway between the flywheel and motor pulley depresses the belt approximately 12,5 mm.

8.25 Injector opening or release pressure

The pressure adjusting screw is adjustable and shall be set to release fuel at a pressure of 10,3 MPa ± 0,34 MPa. This setting shall be checked each time the nozzle is reassembled and after cleaning.

NOTE 15 Use of a commercial injector nozzle bench tester is recommended. ASTM D 613, Annex A4 (Apparatus Assembly and Setting Instructions) provides details which should apply for this International Standard.

CAUTION – Personnel shall avoid contact with the spray pattern from injector nozzles because of the high pressure which can penetrate the skin. Spray pattern performance checks shall be made in a hood or where adequate ventilation ensures that inhalation of the vapours is avoided.

8.26 Injector spray pattern

The injector nozzle spray pattern shall be checked for symmetry and characteristics by inspection of the impression of a single injection made on a piece of filter paper or other slightly absorbent material placed at a distance of approximately 76 mm from the nozzle.

8.27 Indexing handwheel reading

8.27.1 General

Handwheel readings are a simple and convenient indication of engine compression ratio which is a critical variable in the cetane method of test.

NOTE 16 The actual compression ratio is not important but an indication of compression ratio which relates to CN is a useful guide for selecting reference fuels to bracket the sample of diesel fuel oil. Indexing the handwheel when the engine is new, or any time the matched handwheel assembly/cylinder head combination is interchanged or mechanically reassembled, involves setting the variable compression plug, setting the micrometer drum and scale and setting the handwheel reading. ASTM D 613, Appendix A3, (Maintenance Techniques), provides handwheel assembly reworking instructions for application of this International Standard.

8.27.2 Basic setting of variable compression plug

Position the variable compression plug so that the flat surface is just visible and exactly in line with the edge of the threads of the combustion pickup hole, as verified with a straightedge.

8.27.3 Setting handwheel micrometer drum and scale

With the variable compression plug at the basic setting, set the handwheel drum and scale so that the handwheel reads 1,000.

NOTE 17 For cylinders which have been rebored to oversize diameters, the handwheel micrometer drum and scale setting may be offset an appropriate amount to achieve unit operation with comparable handwheel readings. See ASTM D 613 for recommended settings.

8.27.4 Setting handwheel reading

Tighten the small locking handwheel snugly by hand to ensure that the variable compression plug is held in place in the bore. Loosen the lock nut of the large handwheel and remove the locking “L” shaped key. Turn the large handwheel so that the edge of the drum is in alignment with the 1,000 or other selected graduation on the horizontal scale. Reinstall the L-shaped key in the nearest keyway slot of the large handwheel with the shorter leg in the handwheel. Any slight shifting of the handwheel to achieve slot line-up will not affect the indexing. Tighten the lock nut hand-tight to hold the key in place. Remove the locating screw from the drum and rotate the drum so that the zero graduation mark is in line with the selected reading. Locate the screw hole in the drum which lines up with the handwheel hub hole and reinstall the locating screw. Wrench tighten the large handwheel lock nut and recheck that the variable compression plug is properly positioned and the handwheel reading is in accordance with the selected value.

8.28 Basic compression pressure

At a handwheel reading of 1,000, the compression pressure for an engine operated at a standard barometric pressure of 101,3 kPa shall be 3275 kPa ± 138 kPa when read as quickly as possible after shutdown of the engine which has been at standard operating conditions. If the condition is not within limits, recheck the basic handwheel setting and, if necessary, perform mechanical maintenance.

NOTE 18 For engines operated at other than standard barometric pressure, the compression pressure will typically be in proportion to the ratio of the local barometric pressure divided by standard barometric pressure. As an example, an engine located where the barometric pressure is 94,6 kPa would be expected to have a compression pressure of approximately 3060 kPa ± 138 kPa.

$$CP_L = 3275 \times p_L/p_{STD} \quad \text{. . . (2)}$$

where

CP_L is the compression pressure at the local barometer, in kilopascals;

p_L is the barometric pressure at the engine location, in kilopascals;

p_{STD} is the standard barometric pressure, in kilopascals.

NOTE 19 The ratio p_L/p_{STD} is independent of measuring units, provided both elements are in the same units.

ASTM D 613, Annex A4 (Apparatus Assembly and Setting Instructions) provides instructions for checking compression pressure which shall apply for this International Standard. Compression pressure testing using a compression pressure gauge shall be completed in as short a period of time as possible, to avoid the possibility of combustion occurrence due to the presence of any small amount of oil in the gauge or combustion chamber.

8.29 Fuel-pump lubricating oil level

With the engine stopped, sufficient engine-crankcase lubricating oil shall be added to the pump sump so that the level is at the mark on the dip stick.

NOTE 20 As a result of engine operation, especially when the pump barrel/plunger assembly begins to wear, the level in the sump will increase due to fuel dilution as observed through a clear plastic side-plate on the pump housing. When the level rises appreciably, the sump should be drained and a fresh charge of oil added.

8.30 Fuel-pump timing gear-box oil level

With the engine stopped, unplug the openings on the top and at the mid-height of either side of the gear box. Add sufficient engine-crankcase lubricating oil through the top hole to cause the level to rise to the height of the side opening. Replace both openings.

NOTE 21 The pump and timing gear box oil sumps are not connected to each other and the lubrication for the two is independent.

8.31 Setting instrumentation reference pickups

Positioning of the reference pickups is important to ensure that timing of the injection and ignition delay functions is uniform and correct. The two reference pickups, which are identical and interchangeable, are installed in a bracket positioned over the flywheel so that they clear the flywheel indicator which triggers them. Position each pickup in the bracket so that it is properly referenced to the flywheel indicator in accordance with the instructions supplied with the specific pickup. Measurement of pickup to flywheel indicator clearance, if required, shall be made using a non-magnetic feeler gauge.

8.32 Setting injector pickup gap

Set the air gap to typically 1 mm (0,040 in) with the engine stopped.

NOTE 22 Individual pickups may require more or less air gap to obtain steady meter operation when the engine is ultimately running. However, too little gap can cause the ignition delay angle display to drive off scale.

9 Calibration and engine qualification

9.1 Engine compliance

The engine shall be commissioned in a manner that all settings and operating conditions are at equilibrium and in compliance with basic engine and instrument settings and standard operating conditions.

NOTE 23 Engine warm-up requires typically 1 h to ensure that all critical variables are stable.

9.2 Checking performance on check fuels

This engine test does not have any satisfactory standardization fuel blend or blends to qualify the engine. Test one or more of the check fuels as a guide to engine performance.

Engine performance may be judged to be satisfactory if the CN rating obtained on a check fuel is within the following tolerance range:

$$\text{Tolerance limits} = CN_{CF} \pm 1{,}5 \times s_{CF} \qquad \ldots (3)$$

where

CN_{CF} is the average CN of the check fuel calibration data;

1,5 is a selected tolerance limit factor (K) for normal distributions;

s_{CF} is the standard deviation of the check fuel calibration data.

NOTE 24 This statistical tolerance limit factor (K), based on a sample size (n), permits an estimation of the percentage of engines that would be able to rate the check fuel within the calculated tolerance limits. Based on a calibration data set of 17 to 20 ratings, and a value of $K = 1{,}5$, it is estimated that, in the long run, in 19 cases out of 20, at least 70 % of the engines would rate the check fuel within the calculated tolerance limits.

9.3 Check in the case of non-conformity

If the results are outside this tolerance range, check all operating conditions, followed by mechanical maintenance which may require critical parts replacement.

NOTE 25 The injector nozzle can be a very critical factor and this should be the first item checked or replaced.

10 Procedure

10.1 General

Check that all engine operating conditions are in compliance and equilibrated with the engine running on a typical diesel fuel oil.

NOTE 26 ASTM D 613, Appendix X2 (Operating Techniques - Adjustment of Variables) provides additional useful details of engine operation and the adjustment of each of the individual operating variables for application of this International Standard.

Always position the mode selector switch on the ignition delay meter (Mark II and earlier models) to “calibrate” before proceeding with fuel switching, so that violent meter-needle full-scale pegging does not occur. Calibration adjustment should be checked before each rating but never changed during a rating.

10.2 Sample introduction

Pour the sample into an empty fuel tank, rinse the fuel burette, purge any air from the fuel line to the pump and position the fuel-selector-valve to operate the engine on this fuel.

10.3 Fuel flow rate

Check the fuel flow rate and adjust the flow-rate-micrometer of the fuel pump to obtain 13 ml/min consumption. The final flow-rate measurement shall be made over a full 60 s ± 1 s period. Note the flow-rate-micrometer reading for reference.

10.4 Fuel injection timing

After establishing the fuel flow-rate, adjust the injection-timing-micrometer of the fuel pump assembly to obtain a 13,0° ± 0,2° injection advance reading. Note the injection-timing-micrometer reading for reference.

10.5 Ignition delay

Adjust the handwheel to change the compression ratio and obtain a 13,0° ± 0,2° ignition delay reading. Make the final handwheel adjustment in the clockwise direction (viewed from the front of the engine) to eliminate backlash in the handwheel mechanism and a potential error.

10.6 Equilibration

Achieve stable injection advance and ignition delay readings.

NOTE 27 Stable readings should typically occur within 5 min to 10 min.

The time used for the sample and each of the reference fuels should be consistent and shall not be less than 3 min.

10.7 Handwheel reading

Observe and record the handwheel reading as the representative indication of the combustion characteristic for this fuel sample.

10.8 Reference fuel No. 1

Select a secondary reference fuel (“T fuel” and “U fuel”) blend close to the CN of the sample. Prepare a fresh 400 ml or 500 ml batch of the selected reference fuel blend. Introduce reference fuel No. 1 to one of the unused fuel tanks, taking care to flush the fuel lines in the same manner as noted for the sample. Perform the same adjustment and measurement steps used for the sample and record the resulting handwheel reading.

NOTE 28 The handwheel reading versus cetane number relationship based on this procedure is engine- and overhaul-dependent but it can be established for each engine as testing experience is gained after each overhaul. A plot or table of handwheel readings provides a simple guide to selection of the reference fuel.

10.9 Reference fuel No. 2

Select another secondary reference fuel blend which can be expected to result in a handwheel reading that causes the two reference-fuel handwheel readings to bracket that for the sample. The difference between the two reference-fuel handwheel blends shall not exceed 5,5 CN. Typically, blends differing by 5 % (*V/V*) “T fuel” will span approximately 2,7 CN and those differing by 10 % (*V/V*) “T fuel” will span approximately 5,3 CN. Prepare a fresh 400 ml or 500 ml batch of the selected reference fuel blend. Introduce reference fuel No. 2 to the third fuel tank, taking care to flush the fuel lines in the same manner as noted for the sample. Perform the same adjustment and measurement steps used for the sample and first reference fuel and record the resulting handwheel reading.

NOTE 29 Typically, the fuel-flow-rate should be the same for both reference fuels because they are sufficiently similar in composition.

10.10 Number of blends of reference fuels

If the handwheel reading for the sample is bracketed by those of the reference fuel blends, continue the test: otherwise try an additional reference fuel blend(s) until this requirement is satisfied.

10.11 Repeat readings

After operation on a satisfactory second reference fuel blend, perform the necessary steps to rerun reference fuel No. 1, then the sample, and finally reference fuel No. 2. For each fuel, be certain to check all parameters carefully and allow operation to reach equilibrium before recording the handwheel readings. The fuel switching shall be as shown in figure 3 — Sample and reference fuel reading sequence A.

If a sample is tested immediately following one for which the reference fuel No. 2 will be applicable, that reference fuel handwheel reading can be utilized for the new sample. The fuel switching shall thus be as shown in figure 3 — Sample and reference fuel reading sequence B.